Sensitivity to Vertical Resolution

Chandrasekher Narayanan

Avichal Mehra

Carlos Lozano

Nov 08, 2006

HYCOM MEETING 2006

Motivation

- Evaluate the effect of vertical resolution on the oceanic circulations to determine the optimal number of vertical layers in hybrid coordinates.

Methodology

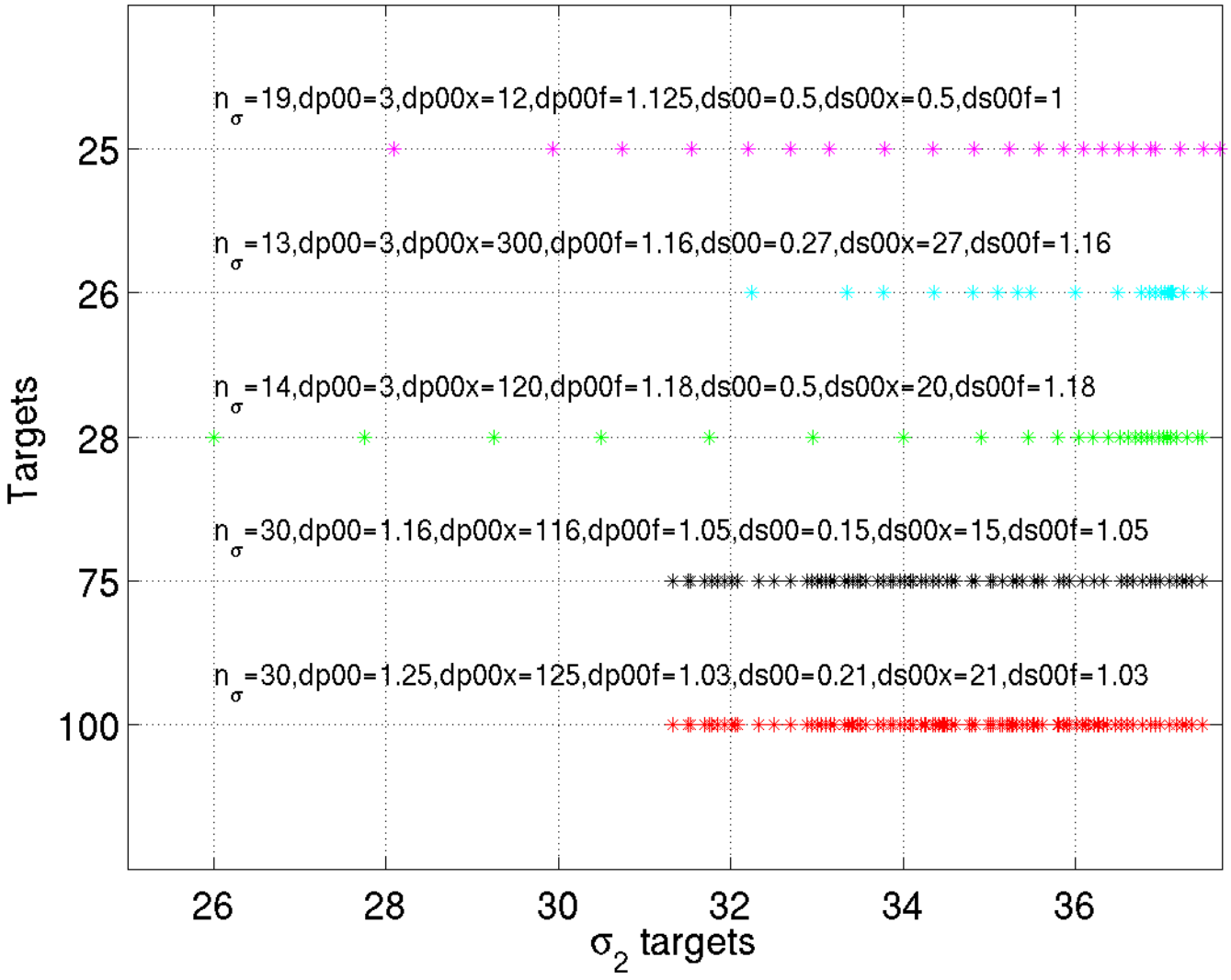
- Five different runs with different vertical hybrid layer parameters
- H25: same parameters as NCEP operational model
- H26: 26 Hybrid levels and targets
- H28: Navy version
- H75: 75 Hybrid levels and targets
- H100: 100 Hybrid levels and targets

H26 hybrid coordinate selection criteria

- Resolve three vertical normal modes in 11 different regions: Caribbean, Labrador, Subtropical North Atlantic, Subtropical South Atlantic, Tropics, Gulf of Mexico, Gulf Stream, GIN sea, Gulf of Maine and Gulf of Saint Lawrence
- Resolve significant Atlantic water masses
- Capture the overflows in Denmark Strait, Iceland Faroe and Mediterranean.
- Shallow water: sigma coordinates up to 150 m depth. Five targets lighter than lightest water in the domain. Target the shelfbreak front in MAB.

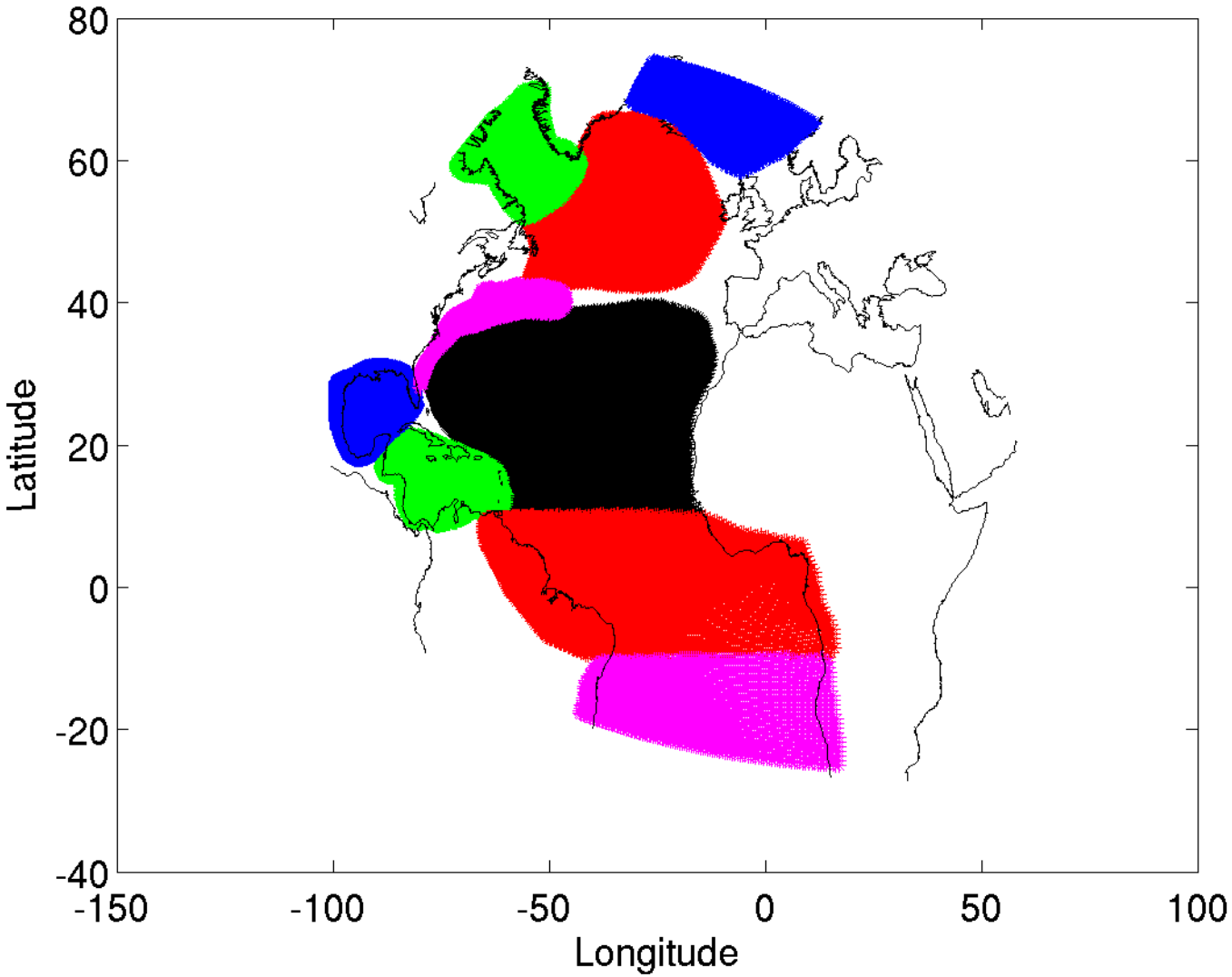
H75, H100

- Targets selected by choosing 6 vertical dynamical modes to capture the variability of the ocean. Combined all the targets and used the criteria: min difference between targets is 0.016 (for 100 layers), 0.0241(for 75 layers)
- Verified that the Denmark Strait, Iceland Faroe and Mediterranean Overflows are well resolved.
- Verified that the significant Atlantic water masses are well resolved.


n_σ=19,dp00=3,dp00x=12,dp00f=1.125,ds00=0.5,ds00x=0.5,ds00f=1
n_σ=13,dp00=3,dp00x=300,dp00f=1.16,ds00=0.27,ds00x=27,ds00f=1.16
n_σ=14,dp00=3,dp00x=120,dp00f=1.18,ds00=0.5,ds00x=20,ds00f=1.18
n_σ=30,dp00=1.16,dp00x=116,dp00f=1.05,ds00=0.15,ds00x=15,ds00f=1.05
n_σ=30,dp00=1.25,dp00x=125,dp00f=1.03,ds00=0.21,ds00x=21,ds00f=1.03
Targets
25
26
28
75
100
26
28
30
32
34
36
σ2 targets

Model Configuration

- 1/3 ° horizontal resolution (421 x 300), curvilinear coordinates
- Varied vertical resolution (25,26,28,75 and 100 hybrid levels)
- 6 hourly GFS forcing (momentum, thermal)
- Climatological hydrography (for initialization)
- Climatological rivers
- Open boundary conditions with buffer zones
  (one invariant formulation)
- Surface Montgomery Potential Algorithm
- Start date: 08/01/04
- Horizontal diffusivity/viscosity: visco2 = 0.1, visco4 = 0;
  » veldf2 = 0.0075, veldf4 = 0.01
- No tides or atmospheric pressure forcing
- No data assimilation

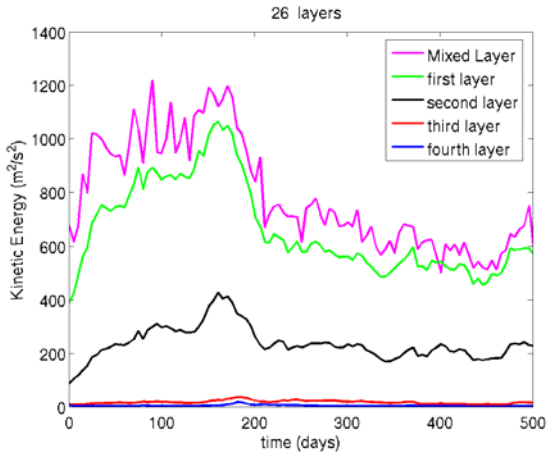

80
60
40
20
0
-20
-40
Latitude
-150
-100
-50
0
50
100
Longitude

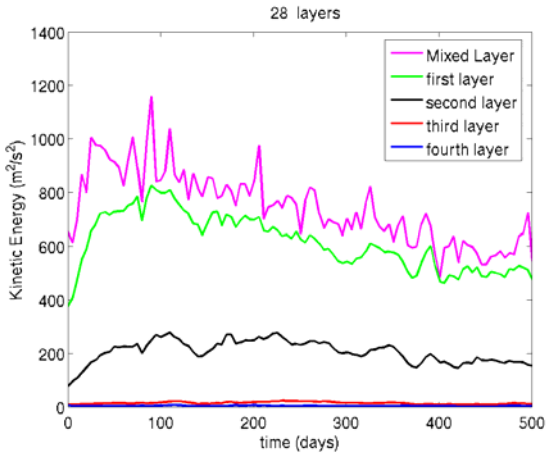
Analysis

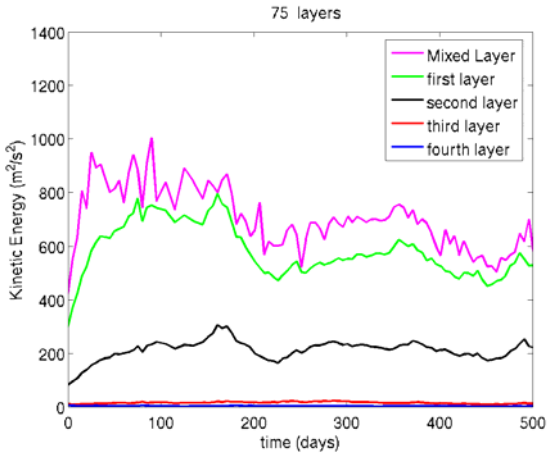
- Kinetic Energy
- Mean and Variance of Salinity and Density
- Deep TS characteristics
- Mixed Layer depth
- Coastal Ocean shelf break front characteristics
- Circulation Patterns
- Transports

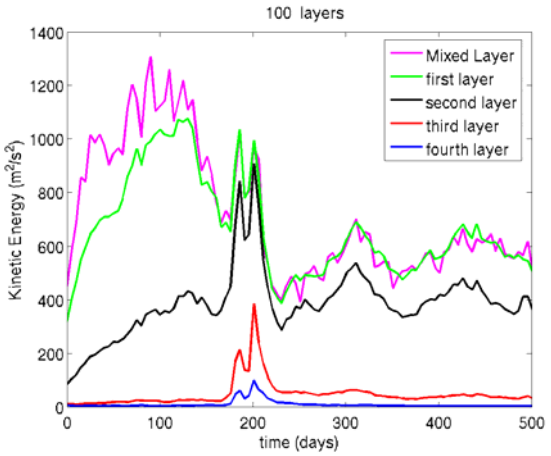
Kinetic Energy

Gulf Stream

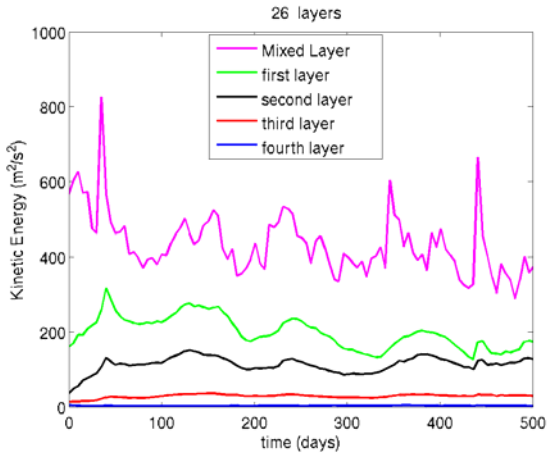

26 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500

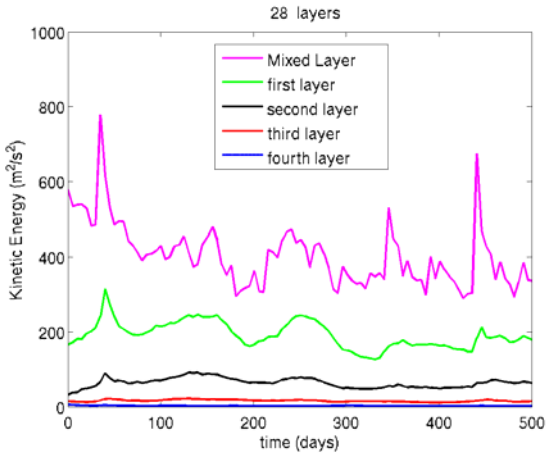

28 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500

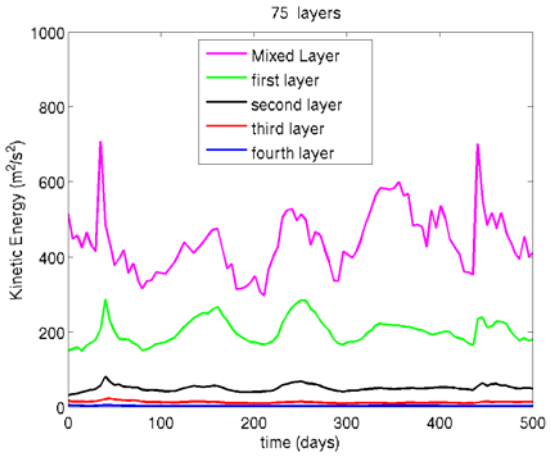

75 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500

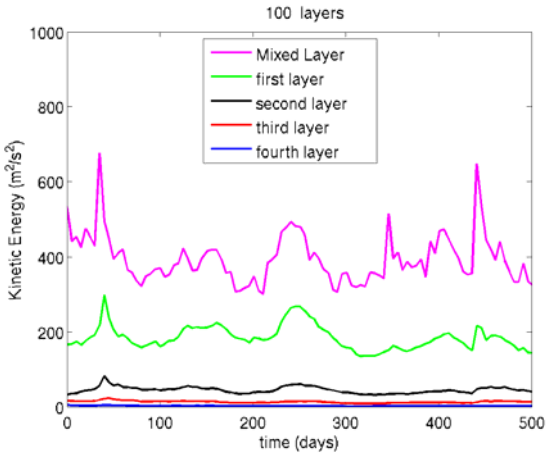

100 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500

Caribbean


26 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
0
100
200
300
400
500


28 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
0
100
200
300
400
500


75 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
0
100
200
300
400
500

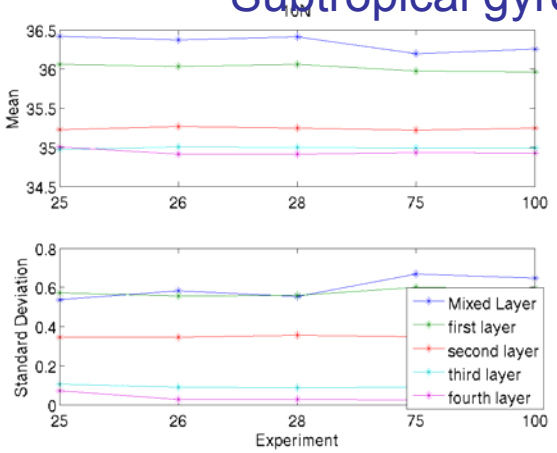

100 layers
Mixed Layer
first layer
second layer
third layer
fourth layer
Kinetic Energy (m²/s²)
time (days)
0
200
400
600
800
1000
0
100
200
300
400
500

Statistics

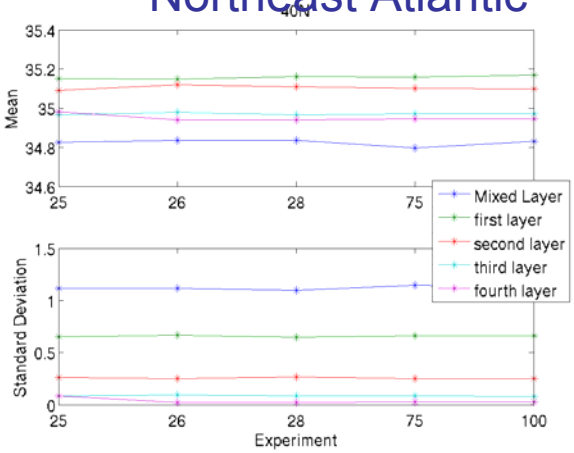
- Mean and standard deviation of density

After 540 days

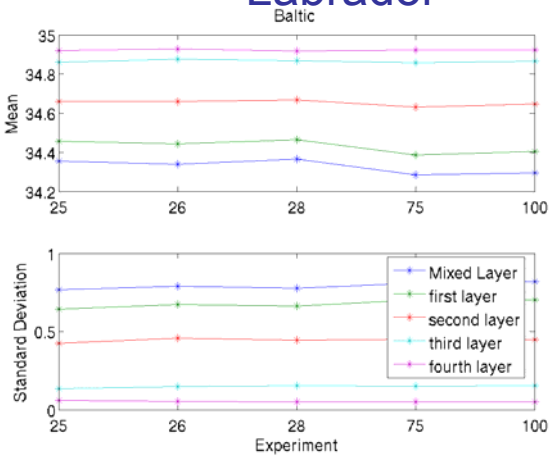
Subtropical gyre



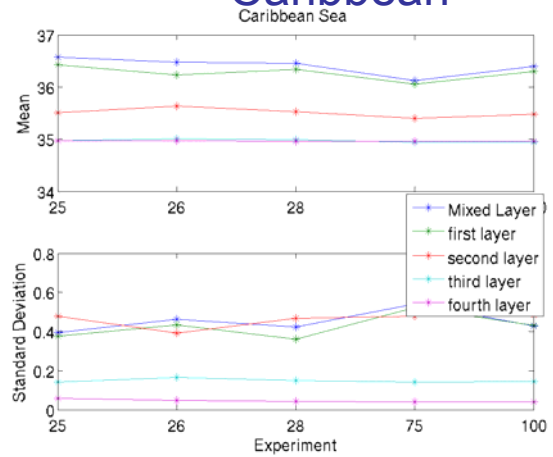
Northeast Atlantic



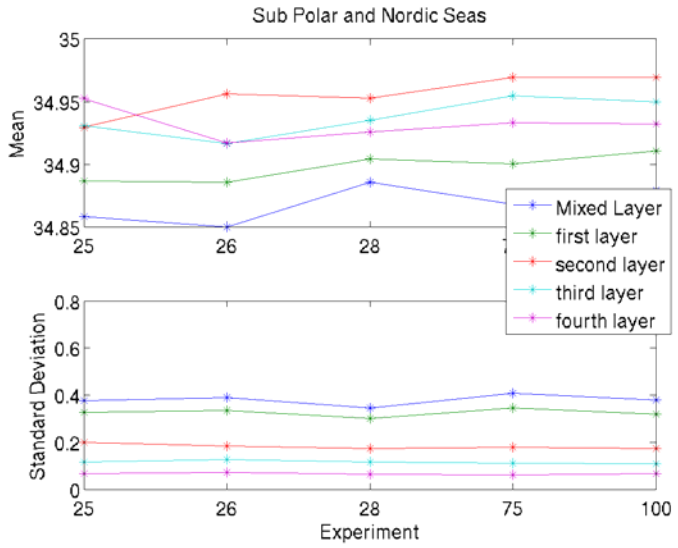
Labrador



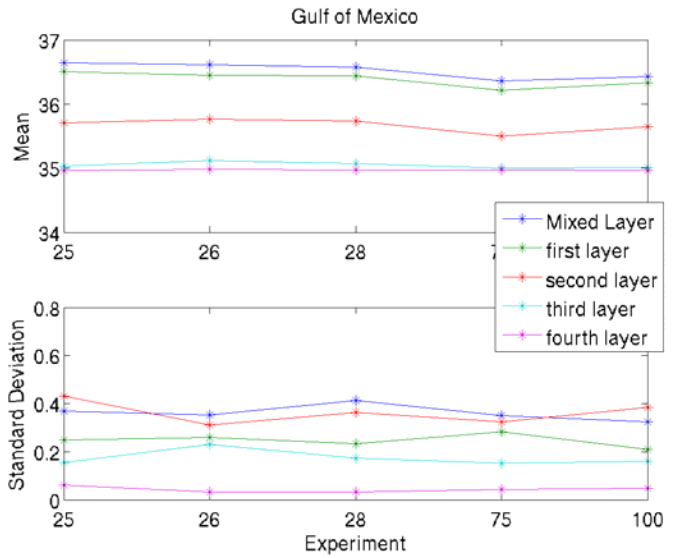
Caribbean



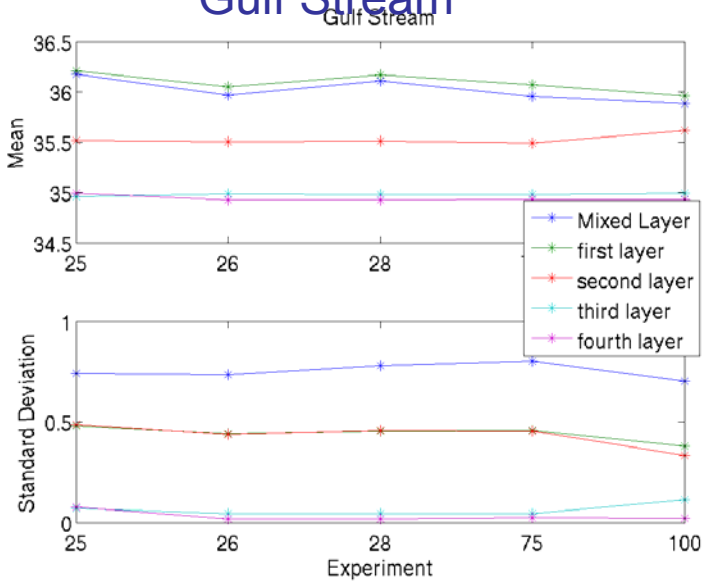
Sub Polar and Nordic Seas



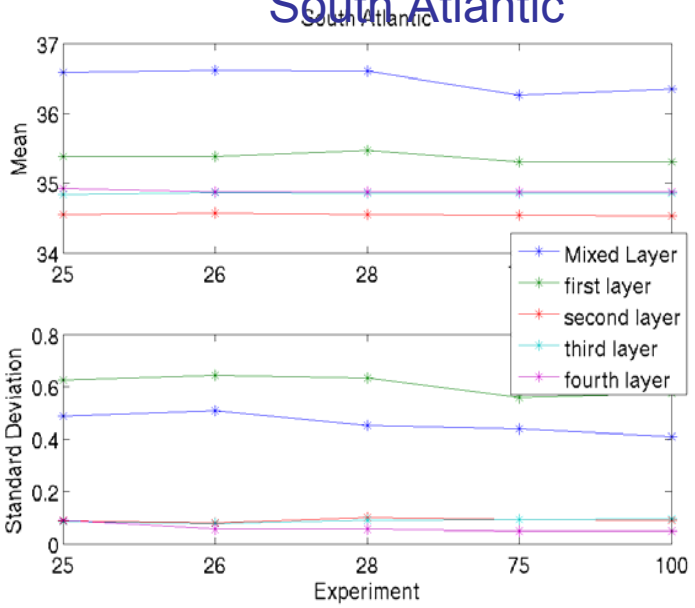
Gulf of Mexico



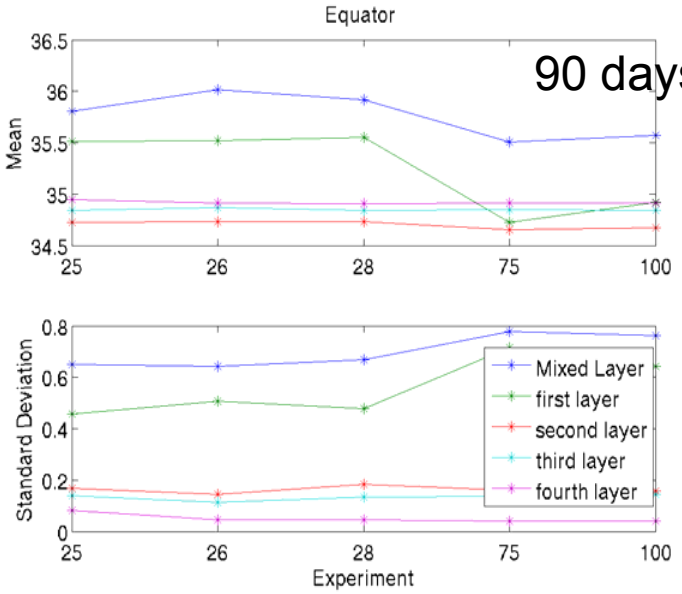
Gulf Stream

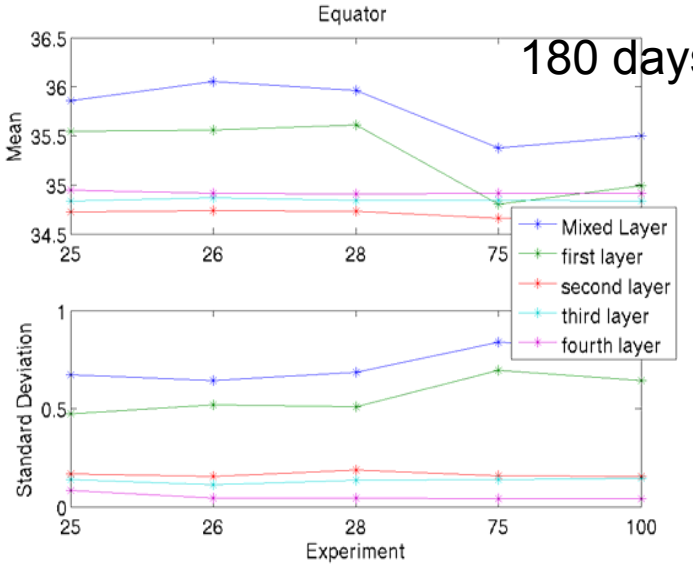


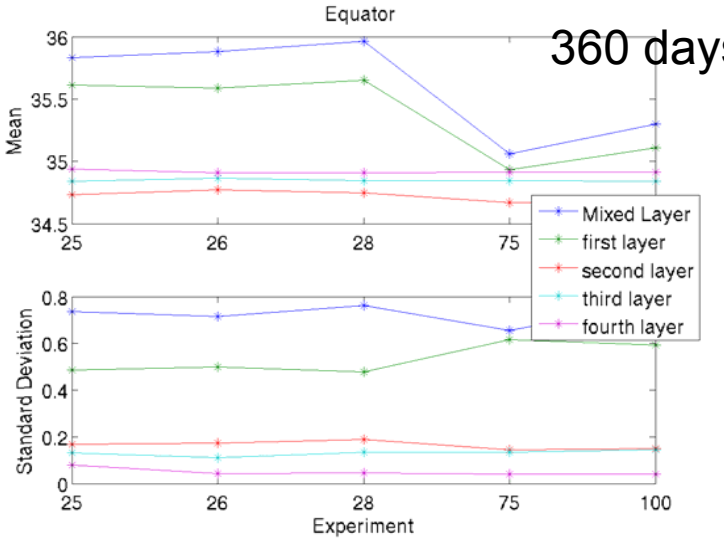
South Atlantic

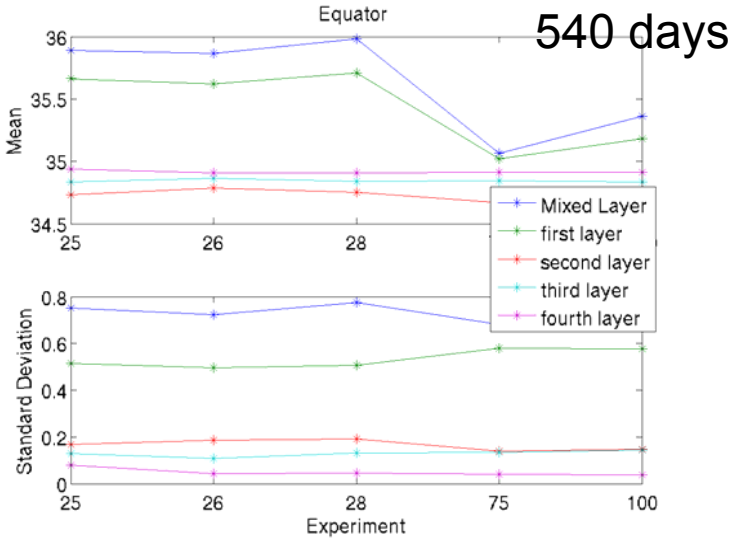


Equator

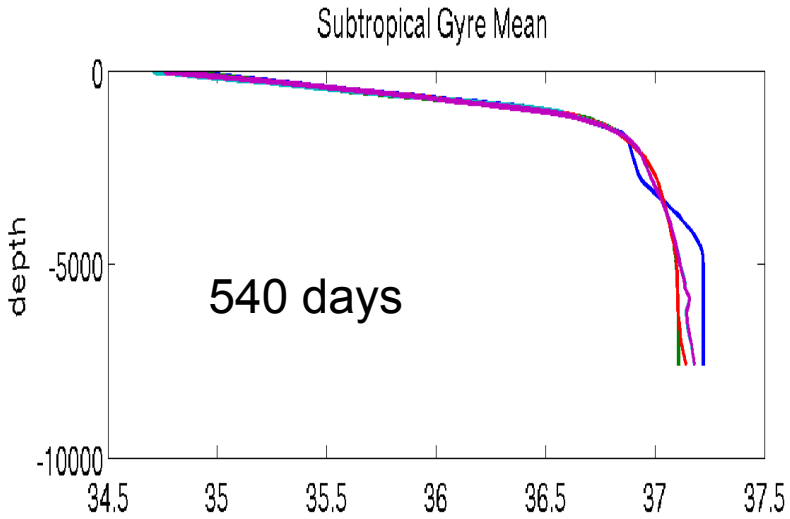

Equator
90 days
Mean
Standard Deviation
Experiment
Mixed Layer
first layer
second layer
third layer
fourth layer

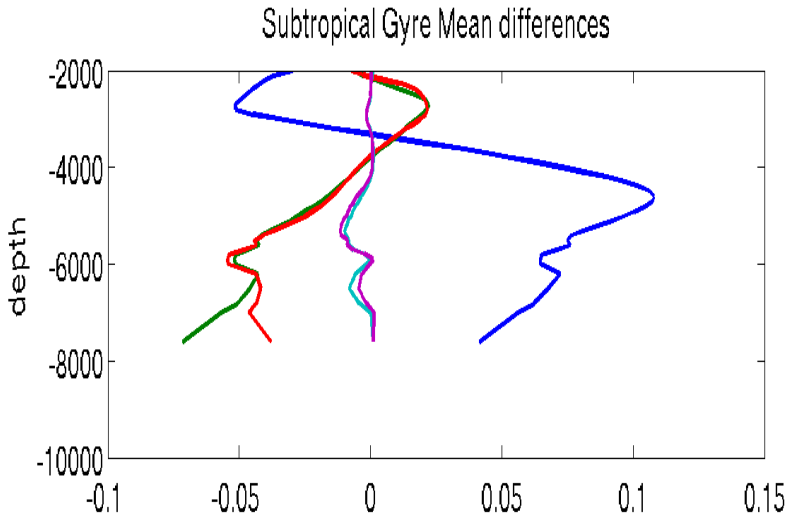

Equator
180 days
Mean
Standard Deviation
Experiment
Mixed Layer
first layer
second layer
third layer
fourth layer

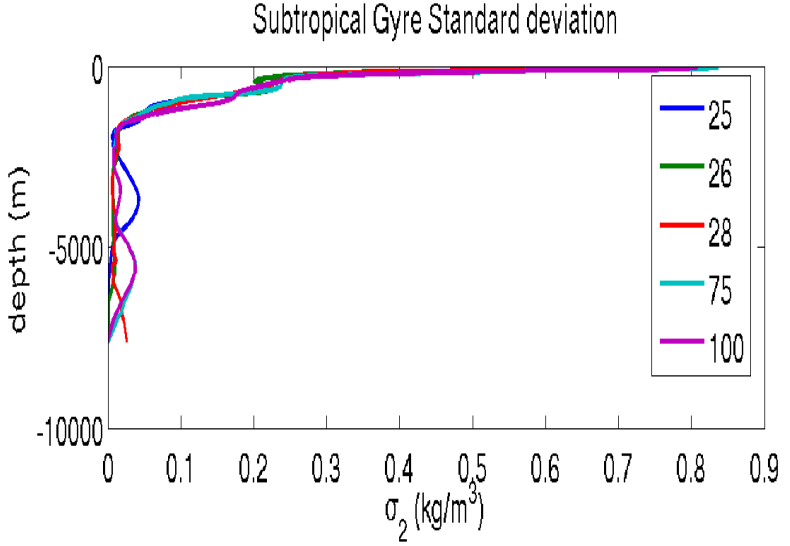

Equator
360 days
Mean
Standard Deviation
Experiment
Mixed Layer
first layer
second layer
third layer
fourth layer

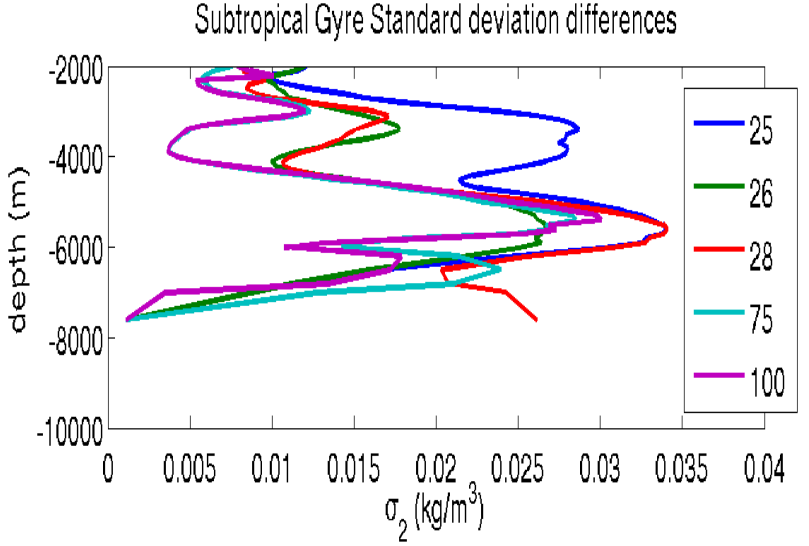

Equator
540 days
Mean
Standard Deviation
Experiment
Mixed Layer
first layer
second layer
third layer
fourth layer

Subtropical Gyre mean density and differences from initial conditions

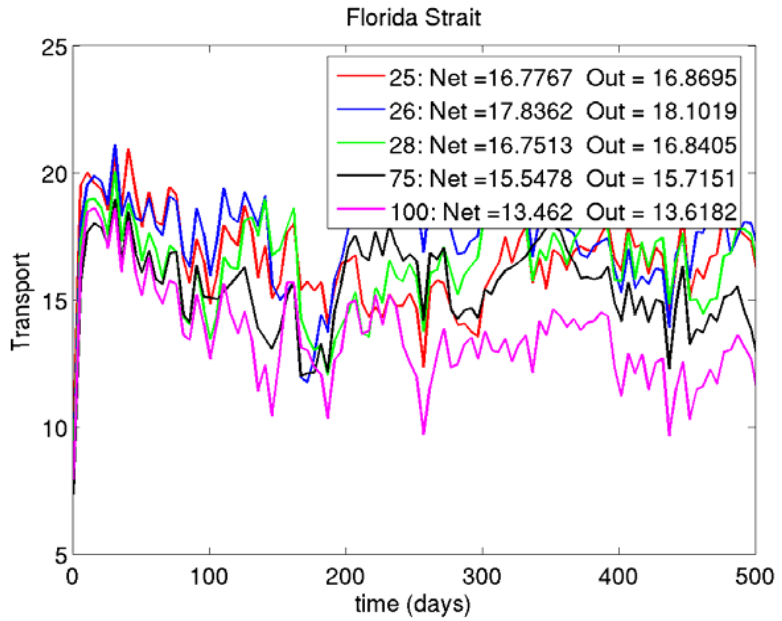


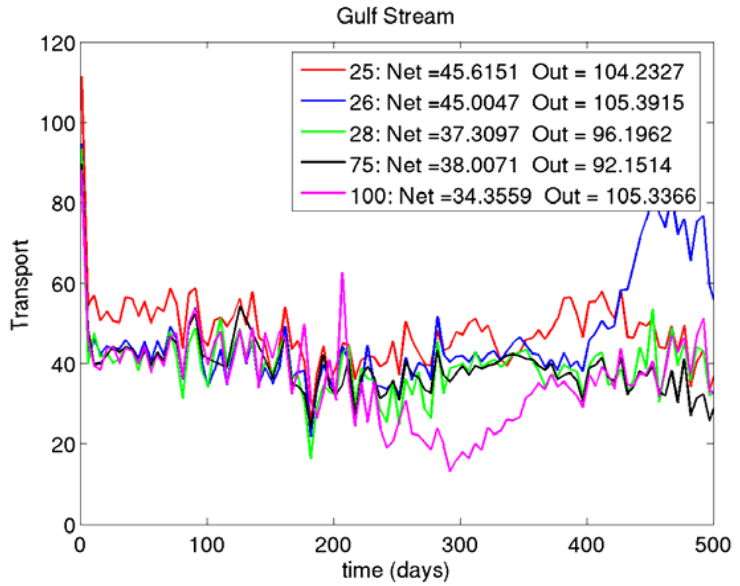


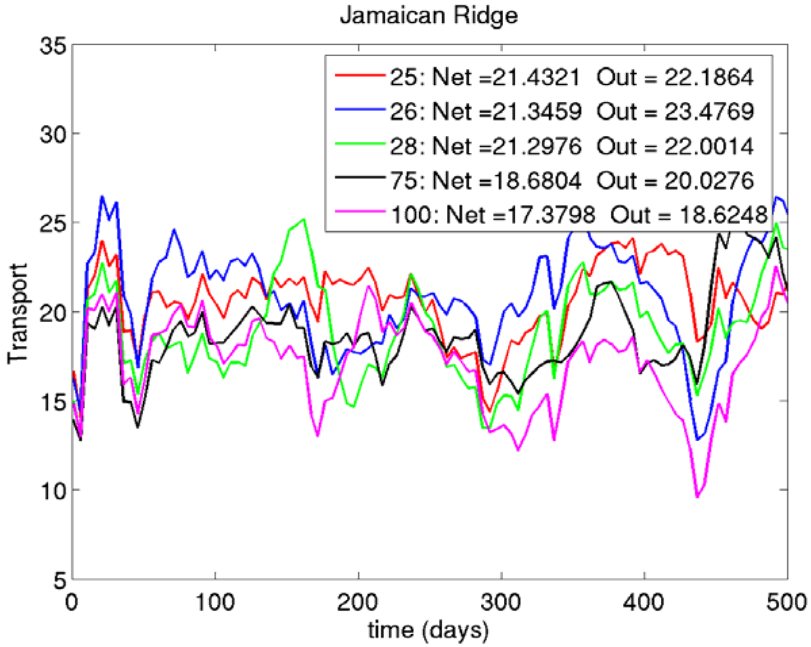


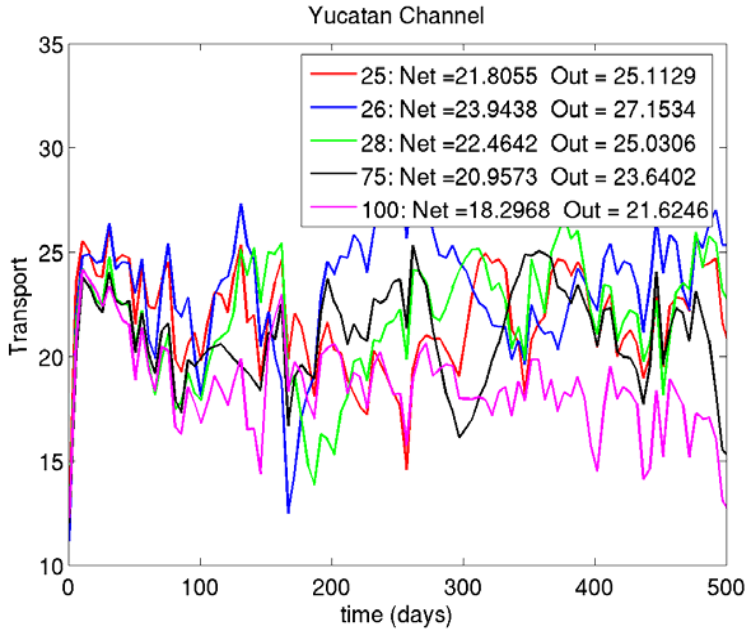


Transports

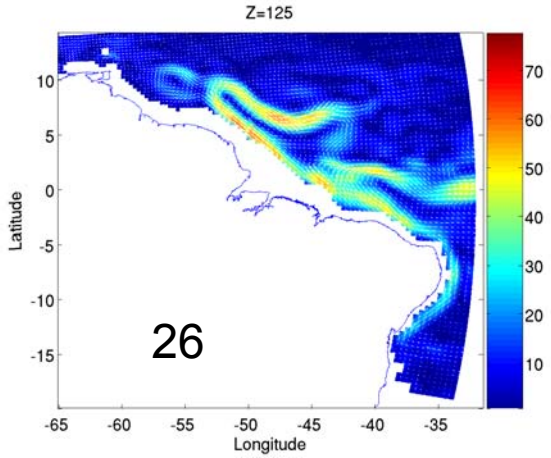

Florida Strait
25: Net =16.7767 Out = 16.8695
26: Net =17.8362 Out = 18.1019
28: Net =16.7513 Out = 16.8405
75: Net =15.5478 Out = 15.7151
100: Net =13.462 Out = 13.6182
Transport
time (days)

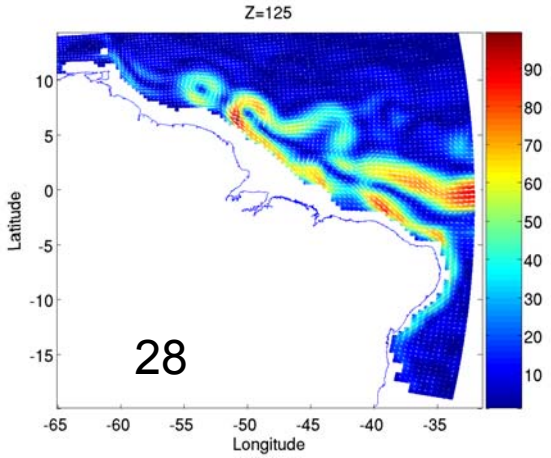

Gulf Stream
25: Net =45.6151 Out = 104.2327
26: Net =45.0047 Out = 105.3915
28: Net =37.3097 Out = 96.1962
75: Net =38.0071 Out = 92.1514
100: Net =34.3559 Out = 105.3366
Transport
time (days)

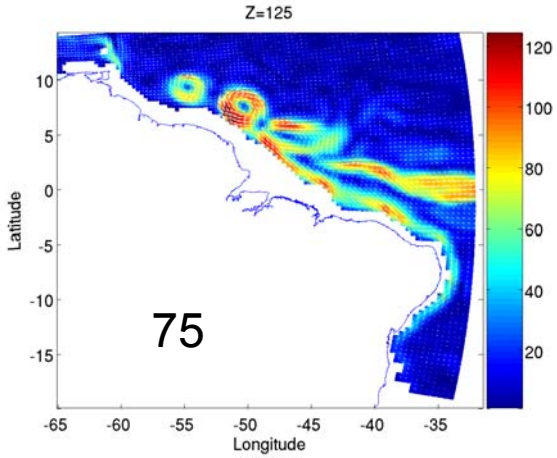

Jamaican Ridge
25: Net =21.4321 Out = 22.1864
26: Net =21.3459 Out = 23.4769
28: Net =21.2976 Out = 22.0014
75: Net =18.6804 Out = 20.0276
100: Net =17.3798 Out = 18.6248
Transport
time (days)

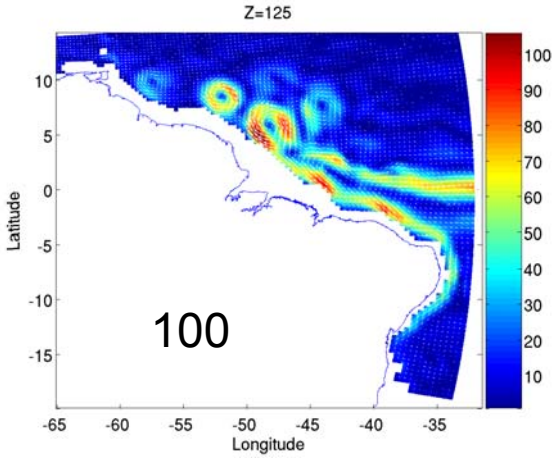

Yucatan Channel
25: Net =21.8055 Out = 25.1129
26: Net =23.9438 Out = 27.1534
28: Net =22.4642 Out = 25.0306
75: Net =20.9573 Out = 23.6402
100: Net =18.2968 Out = 21.6246
Transport
time (days)

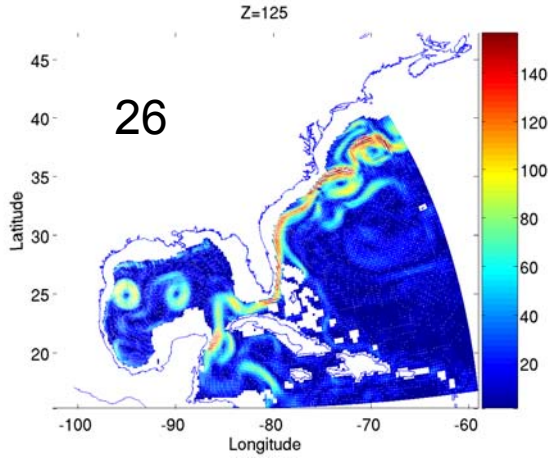
Circulation pattern after 540 days

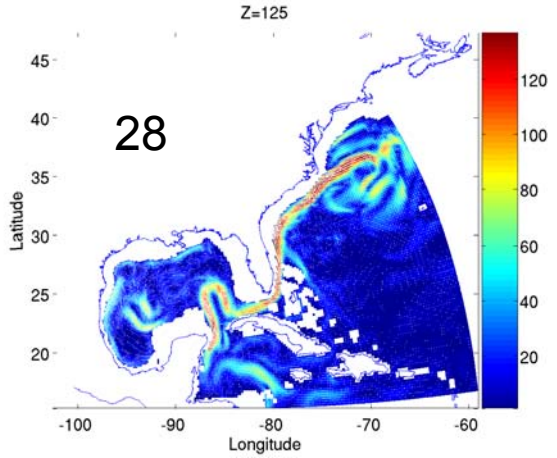

Z=125
26
Latitude
Longitude
10
5
0
-5
-10
-15
-65
-60
-55
-50
-45
-40
-35
70
60
50
40
30
20
10

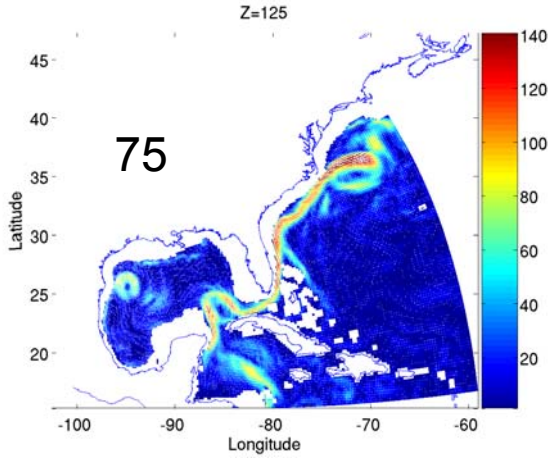

Z=125
28
Latitude
Longitude
10
5
0
-5
-10
-15
-65
-60
-55
-50
-45
-40
-35
90
80
70
60
50
40
30
20
10

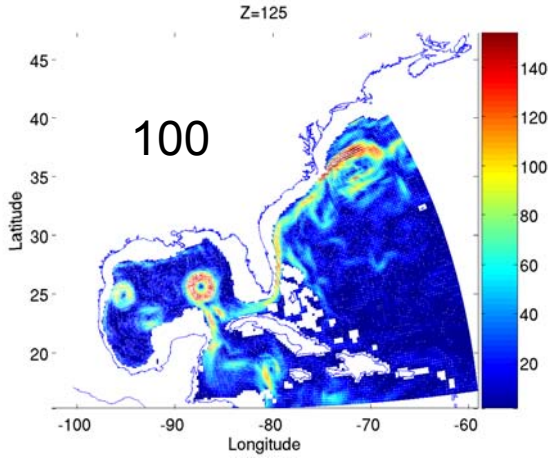

Z=125
75
Latitude
Longitude
10
5
0
-5
-10
-15
-65
-60
-55
-50
-45
-40
-35
120
100
80
60
40
20


Z=125
100
Latitude
Longitude
10
5
0
-5
-10
-15
-65
-60
-55
-50
-45
-40
-35
100
90
80
70
60
50
40
30
20
10

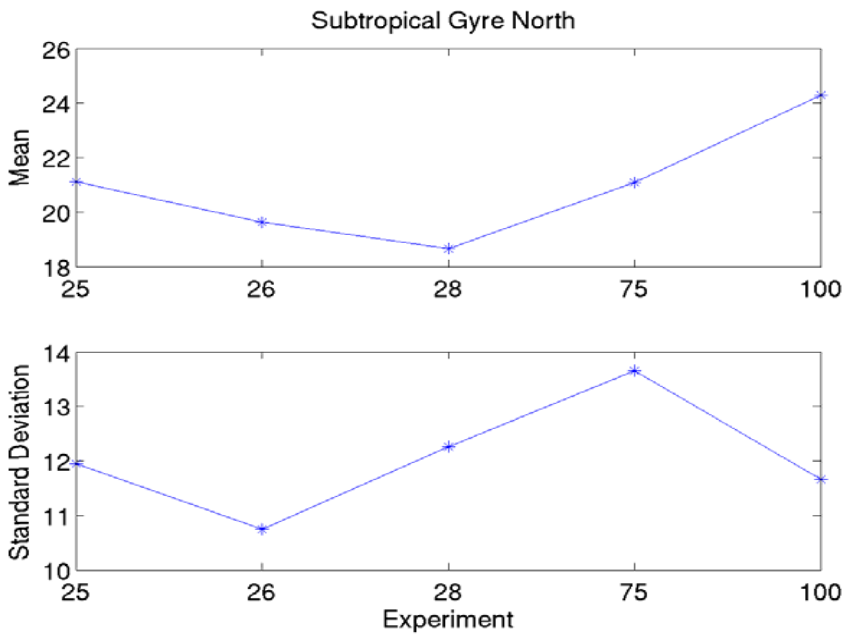

Z=125
26
Latitude
Longitude
45
40
35
30
25
20
-100
-90
-80
-70
-60
140
120
100
80
60
40
20

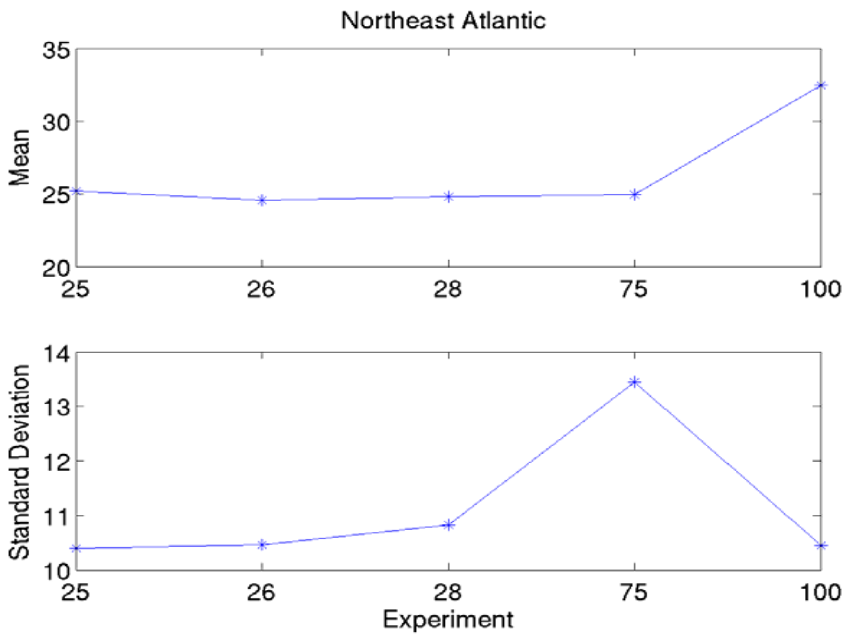

Z=125
28
Latitude
Longitude
45
40
35
30
25
20
-100
-90
-80
-70
-60
120
100
80
60
40
20

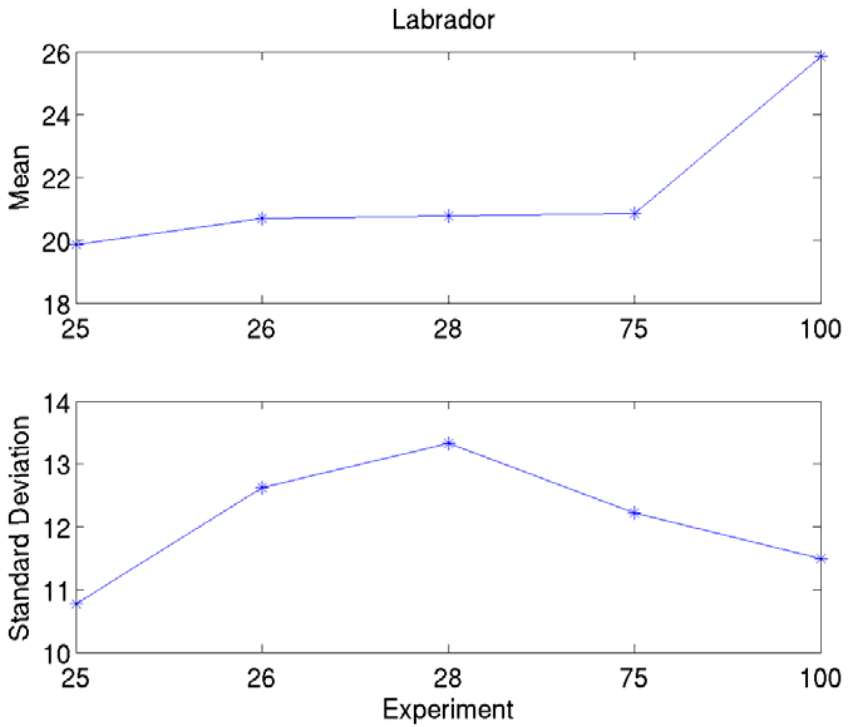

Z=125
75
Latitude
Longitude
45
40
35
30
25
20
-100
-90
-80
-70
-60
140
120
100
80
60
40
20

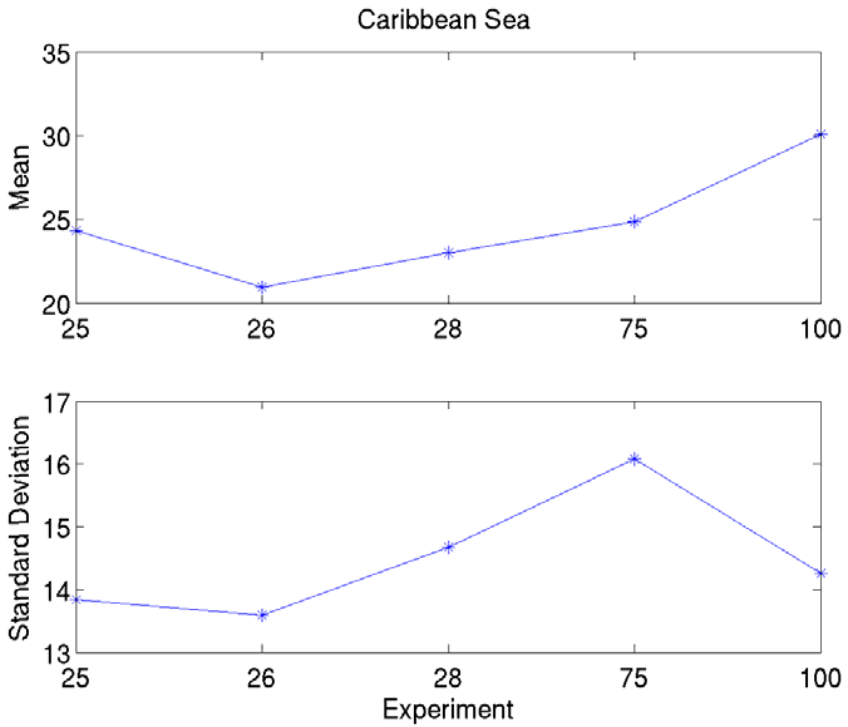

Z=125
100
Latitude
Longitude
45
40
35
30
25
20
-100
-90
-80
-70
-60
140
120
100
80
60
40
20

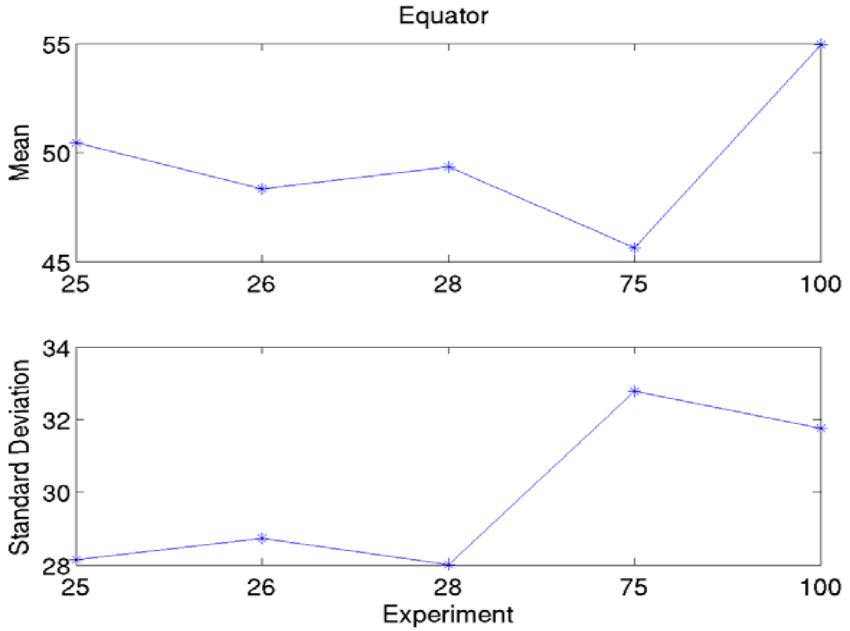
Mixed Layer Depth

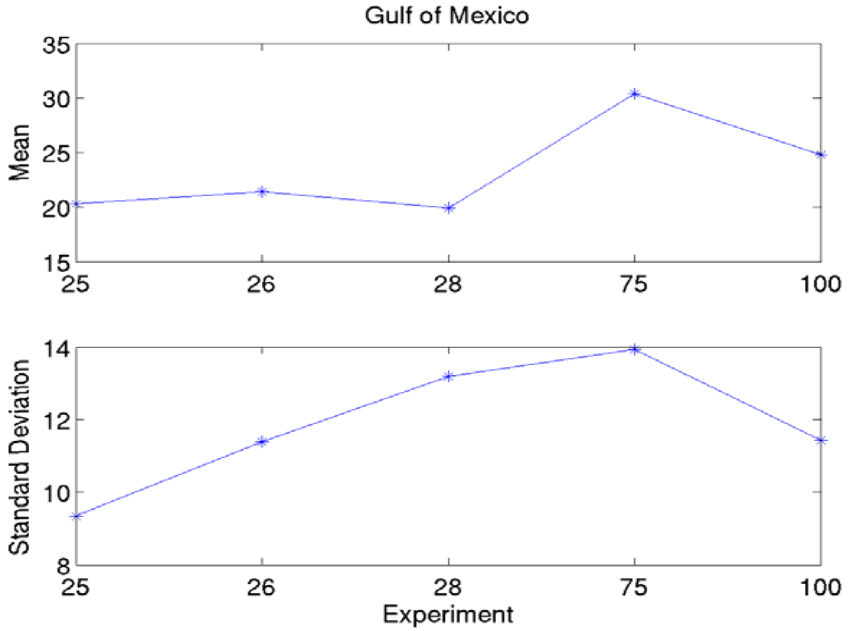

Subtropical Gyre North
Mean
Standard Deviation
Experiment
25
26
28
75
100

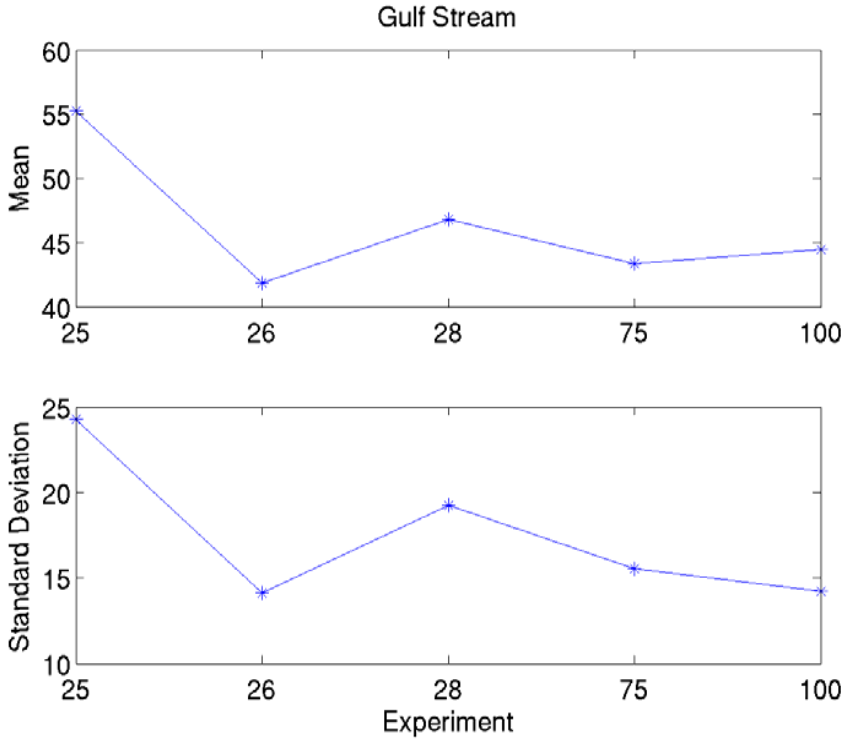

Northeast Atlantic
Mean
Standard Deviation
Experiment
25
26
28
75
100

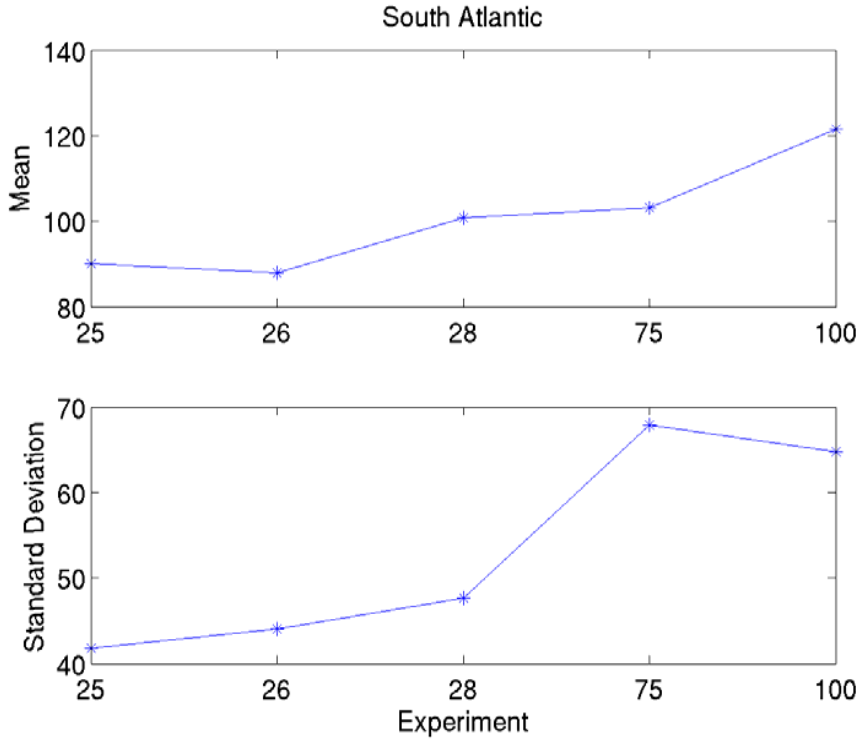

Labrador
Mean
Standard Deviation
Experiment
25
26
28
75
100


Caribbean Sea
Mean
Standard Deviation
Experiment
25
26
28
75
100


Equator
Mean
55
50
45
25
26
28
75
100
Standard Deviation
34
32
30
28
Experiment


Gulf of Mexico
Mean
35
30
25
20
15
25
26
28
75
100
Standard Deviation
14
12
10
8
Experiment


Gulf Stream
Mean
60
55
50
45
40
25
26
28
75
100
Standard Deviation
25
20
15
10
Experiment


South Atlantic
Mean
140
120
100
80
25
26
28
75
100
Standard Deviation
70
60
50
40
Experiment

Conclusions

- The simulations are very sensitive to the hybrid coordinate parameters.
- The circulation patterns in the simulations are very different
- The deep water masses are very different in the 25, 26 and 28 simulations from the 75 and 100 simulations that are similar.
- The kinetic energy and the mean and standard deviations suggest that the 75 and 100 levels results are similar.
- 26 is in closer agreement with 75,100 than 25

Implications and Future Work

- We use the 26 layer for future operational implementation
- Obtain the optimal number of layers
- What is the implication for climate scale work ?
- Run the same using 1/12 resolution